

5.5 Left-Turn Phase Operation

Background

Left-turn movements controlled by traffic signals can be operated in several ways and combinations. The options for left-turn operation typically involve trade-offs between safety and efficiency. Left-turn signal phasing types include:

- **Permitted-only** displayed with a green ball or a flashing yellow arrow display - (vehicle may turn left but must yield to conflicting traffic including cyclists and pedestrians in the crosswalk).
- **Protected-only** displayed with a green arrow display - (vehicle may turn left with right-of-way and will not conflict with any other movements).
- **Protected/permitted** (leading left-turn) or permitted/protected (lagging left-turn).

Protected-only left-turn operation minimizes potential conflicts with other movements but may require a longer cycle length to operate and may increase delays to the left-turn and other movements, including pedestrian movements.

Permitted-only operation can allow for shorter cycle lengths as left-turn phase timing is not needed but may not adequately service higher left-turn movement volumes or where there are high opposing through volumes. Permitted-only operation will also typically result in a higher number of potential conflicts with other movements, including concurrent pedestrian phases, but may shorten pedestrian delays.

Protected/permitted left-turn operation allows for both a protected and permitted portion of the phase to balance these tradeoffs where conditions allow.

Practice: In general, the City provides protected-only or protected/permitted left-turn phasing where permitted-only operation allows too much potential for conflict or results in excessive delay for the left-turning vehicles, or where:

- There has been a documented **crash history** necessitating a change in operation, or
- **Sight distance** or other site conditions are unsuitable for permissive left-turn operation, or
- Protected operation would provide **improved efficiency** (typically at high volume left-turn locations)

The City seeks to provide the least restrictive form of left-turn control that provides an appropriate balance between the crash history, potential for conflict and mobility of all users.

The City has developed guidelines for the assessment of left-turn phase operation based on *NCHRP Report 812, Signal Timing Manual 2nd Edition* (FHWA, 2015). These national guidelines provide criteria for the selection of left-turn phasing and were adapted and modified for City of Boulder specific conditions and local data. These guidelines are provided on the following pages and incorporate the following considerations when assessing left-turn phase operation for an individual signalized approach, where sight distance or other site-specific considerations did not already dictate use of a more restrictive mode of phasing than permitted left-turn operation:

- Left-turn and opposing lane volumes
- # of approach left-turn lanes and opposing left-turn lanes
- Speed and geometry of opposing traffic
- Crash history
- Locations where a left-turn movement intersects high bicyclist or pedestrian volumes

When considering a change in left-turn phasing, an operational analysis will be performed and potential operational and safety issues will be identified so that the impacts of a phasing change are understood.

The City may vary left-turn phasing type by time-of-day to best match conditions that vary over the course of the day, including lead-lag left-turn operation. Historically, lead-lag operation and potential for a “yellow trap” condition has required the lead phase to be protected-only and has only been used where progression benefits have offset this restriction. However, the use of a four-section flashing-yellow-arrow (FYA) head addresses this issue and allows lead-lag phasing for coordinated operation with mitigation of a “yellow trap” condition.

At “T” intersections where the side street left-turn movement has no conflicting vehicular movement, the City considers variable left-turn operation triggered by a pedestrian call. If no pedestrian call occurs, the left-turn may operate as protected-only (green arrow); if there is a pedestrian call, the left-turn operates permitted-only (FYA).

The City is evaluating the feasibility and practical considerations associated with extending a variation of this dynamic left-turn service practice to four-way intersections. At locations where the pedestrian service occurs only in response to a pedestrian actuation, consideration may be given to operating the associated left-turn movement in protected/permitted mode on cycles where there is no pedestrian actuation, and in protected-only mode on cycles when a pedestrian is served.

For new signal installations, initial left-turn phasing is typically set based on the physical criteria above and with consideration for operational modeling that may have been provided (a traffic impact study for an adjacent proposed development, for example). Over time, any changes to left-turn operations are then considered based on staff observations, in response to citizen requests, or at such time issues are identified through the Boulder Safe Street report, design projects where crash and operation data is reviewed, and/or from the Police department.

The following guidelines are to be utilized by the City Engineer to determine the least-restrictive left-turn operational mode that can meet operational and safety objectives, with application of engineering judgement. If an assessment is made to modify phasing to address an issue that is specific to a time of day, time-of-day phasing may be utilized.

For locations with existing permitted operation with a standard three-section red-yellow-green “ball” configuration, the City Engineer may consider a change to a four-section, Flashing Yellow Arrow (FYA) display in lieu of implementation of protected/permitted phasing, if such a phasing change is suggested by the City criteria.

In addition to the considerations on the guidelines flow diagram on the following page, the engineer will consider:

- Presence of vulnerable population (school aged, senior)
- Minimum sight distance; if AASHTO sight distance minimums cannot be met, protected-only phasing may be implemented
- Impacts of left-turn phasing implementation to the larger system; the engineer should consider potential traffic diversion due to a restrictive phasing decision at one location that could result in undesired/unsafe movements elsewhere

Table 1 (below) provides the basis for assessment of a more restrictive left-turn phase operation based on a critical left-turn crash count. The City Engineer will use these crash counts to evaluate changing from permitted to Flashing Yellow Arrow (FYA), permitted to protected-permitted, or from protected-permitted to protected-only. The crash data will be reviewed to identify if crash trends are specific to a time of day and will implement time of day plan changes to signal timing/phasing, if appropriate. This table is to be used in conjunction with the flow diagram on the following page:

Table 1 - Critical Left-Turn Related Crash Count

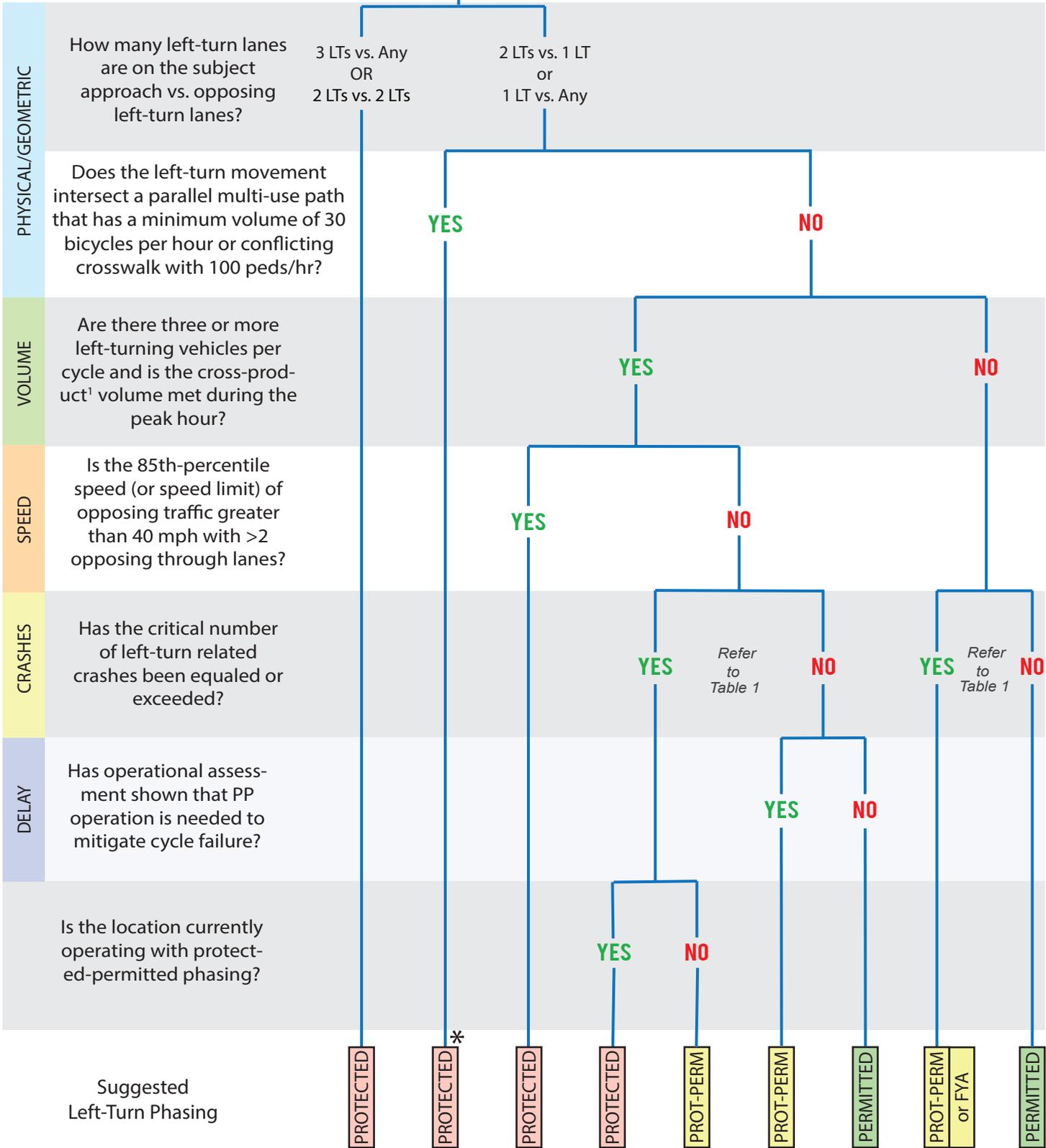
Period during which Crashes Are Considered	Critical Left-Turn Related Crash Count (Crashes Per Period)*
3 Years	3 Crashes

Notes:

* Includes only crashes that may have been mitigated by more restrictive left-turn phasing, or for existing permitted phasing, may have been mitigated by use of a Flashing Yellow Arrow (FYA) display.

LEFT-TURN PHASING GUIDELINES

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¹ Cross-product: For one opposing through lane, $V_{lt} \times V_o > 50,000$; For two+ opposing through lanes $V_{lt} \times V_o > 100,000$; where V_{lt} = left-turn volume on subject approach (veh/hr) and V_o = through+right-turn volume on opposing approach (veh/hr)

* The City Engineer may consider the use of a long Leading Pedestrian Interval (LPI) as an alternative to a change to protected phasing based on bike/ped volumes, where appropriate based on lane geometry, volumes, and signal timing.

Note: These guidelines can be utilized by the City Engineer to assess a location on a peak-period-only, full-time, or other time-of-day condition on a case-by-case basis.

Source: Adapted and modified from the NCHRP Report 812, Signal Timing Manual 2nd Edition (FHWA, 2015) for City of Boulder specific conditions and local data.